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Biofield and Fungicide Seed Treatment Influences on Soybean Productivity, Seed Quality and Weed Community

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Abstract: Soybean production in Iowa USA is among the most productive for rainfed regions in the world. Despite generally having excellent soils, growing season temperatures and rainfall, soybean yields are decreased by weed interference and inadequate available soil water at key stages of crop development. A field study was conducted at two locations in Iowa in 2012 to determine if seed-applied fungicide or biofield treatments influenced weed community, soil volumetric water concentration and soybean yield and quality. Application of biofield treatment resulted in lower density of tall waterhemp density, greater soybean stand density at R8 stage and greater seed pod^{-1} compared to the absence of seed fungicide and biofield. Soil volumetric water content varied by seed fungicide x biofield x date interaction but differences were not consistent among treatment combinations. Overall, seed fungicide and biofield treatments had similar effects on soybean productivity, however additional research is necessary to determine if biofield treatment is a suitable replacement for seed fungicide application.

Key words: Soybean, biofield energy treatment, prickly sida, tall waterhemp, yellow foxtail, yield, seed oil, seed protein, soil volumetric water concentration

INTRODUCTION

Soybean, *Glycine max* (L.) Merr., is the most important pulse crop in the world (FAOSTAT, 2013) providing large quantities of protein and edible oil for direct human and animal consumption. Soybean crops are subjected to significant stressors during the growing season that can negatively impact yield and quality. Stressors can include seedling diseases, weeds, arthropods and inadequate soil water during reproductive development. In the USA, treatment of soybean seed with fungicide can improve stand establishment and subsequent yield (Bradley, 2008). However, seed fungicide treatments increase farmer costs by \$12-25 USD ha^{-1}. An additional factor in their utilization is most seed-applied fungicides are not allowable for certified organic soybean production.

Biofield is an alternative and complementary medicine (Rubik, 2002). The hypothesized mode of action of biofield involves weak electromagnetic interactions with homeostasis and homeodynamics (Rubik, 2002). Although, the mode of action is not well understood, application of biofield treatment was documented to increase growth and yield of lettuce and tomato over that of untreated plants (Shinde *et al*., 2012). In an unrelated study, biofield was documented to influence patchouli (*Pogostemon cablin* Benth.), a crop grown for essential oil. Effects of biofield on patchouli included increased growth during change from *in vitro* to *in vivo* phases and increased density of stomatal cells and epidermal hairs (Patil *et al*., 2012). Epidermal hairs, simple and glandular secreting can have numerous functions in plants (Wagner *et al*., 2004) including decreased water loss from alfalfa (Lenssen *et al*., 2001). Although, it is one of the most important crops in the world, information is not available on the influence of biofield treatment on soybean productivity. Consequently, a field trial was conducted to determine the influence of biofield and seed fungicide treatments on soybean growth and development, yield, weed community and soil volumetric water content.

MATERIALS AND METHODS

The experimental sites were located on Iowa State University research farms near Boone (42° 01' N 93° 45' W) and Chariton (40°59' N 93°25' W), Iowa. Each farm is equipped with an automated recording weather station. Additionally, long-term weather data are available for each site. The research area at Boone was located in a Clarion loam soil (fine-loamy, mixed, superactive, mesic Typic Hapludolls); the research area at Chariton was located in Haig silt loam soil (fine, smectitic, mesic Vertic Argiaquolls). Previous crop was maize for both sites. Preplant soil sampling was done to 0-15 and 15-30 cm depths in April to determine if fertilizer applications were

necessary. The pH, available P (Mehlich-3), K and micronutrient concentrations were suitable for soybean production (Table 1), so fertilizer applications were not required (Sawyer *et al*., 2002).

The experiment consisted of a complete factorial treatment structure of fungicide seed treatment and biofield energy treatment. The fungicide seed treatment, formulated ApronMAXX was applied at the rate of 44.4 mL/100 kg seed, providing 3.75 g of mefenoxam and 2.5 g of fludioxonil. Biofield treatment was applied from a distance of 0.5 m with seed for each plot treated separately. The experimental design was a factorial of fungicide seed treatment and biofield energy treatment in a randomized complete block design with four replicates at each site. Individual plot size was 3.0 m wide and 9.1 min length. Plots were planted in zero tillage system at both sites using soybean P92M40 at 345,800 PLS ha^{-1} on 8 June, 2012 with a Kinze 3000 planter equipped with no-till disc openers on 76 cm row spacing. Weed control was done with preplant application of formulated S-metolachlor and metribuzin on 25 April, followed by in-crop glyphosate applications on 5 and 24 July at Chariton and 5 and 19 July at Boone. Soil volumetric water content was determined at 8 and 20 cm depths on 12 and 24 July and 3 August at each location by time domain reflectometry.

Stand densities were determined by counting all plants in two 1 m lengths of row in each plot at the VC, V2 and R8 growth stages (Fehr *et al*., 1971). Weed densities were determined by species prior to in-crop herbicide application with five 0.10 m^2 circular quadrats in each plot. Total weeds were calculated by summing individual species counts for each plot. Crop aboveground biomass (biomass) was determined at R5, prior to leaf drop, by clipping all plants at ground level in 1 m row length. Samples were oven-dried at 55°C and weighed to determine biomass. Just prior to harvest, plant heights were measured.

Additionally, all plants were counted in a 1 m row length and five were sampled for yield component determination. From each five-plant sample, number of branches, nodes, pods and total seed and total seed weight were determined. Seed per pod and individual seed weight were calculated. The two center rows from each soybean plot were harvested for yield with a self-propelled combine on 8th October at both sites. Yield sample weights were determined with an onboard computerized scale. Subsamples of seed were saved from each plot and used for determination of oil and protein concentrations by calibrated NIRS (Model 7200, Perten Industries, Springfield, Illinois). Harvest index was calculated as seed yield divided by biomass.

Statistical analysis: The experiment was a complete factorial in a randomized complete block design conducted at two locations. The PROC MIXED procedure of SAS (v9.2) was used for analysis of all parameters. Fungicide seed treatment (yes and no) and biofield treatment (yes and no) composed the factorial and including location were considered fixed effects. Replicate and interactions with replicate were considered random effects. Means separations were done with least square means procedure. For density of individual and total weeds, location was considered a repeated measure, resulting in normalized variance for each location.

RESULTS AND DISCUSSION

Weather: Overall, the 2012 growing season was warmer and drier than normal. Growing season precipitation was substantially below long-term for May through September at Boone and Chariton (Table 2). Boone and Chariton received 47 and 55% of normal precipitation, respectively during the growing season. April precipitation at Chariton was the only month when precipitation exceeded

Table 1: Preplant soil nutrient status for two depths at two locations, 2012

Location	Depth (cm)	P	K	Ca	Mg	Fe	Zn	pH	OM (g kg^{-1})	NO_3-N (mg kg^{-1})
		(mg kg^{-1})								
Boone	0-15	50	194	2598	305	186	0.4	5.9	38	2.3
	15-30	27	128	2703	323	173	0.8	6.1	33	3.8
Chariton	0-15	14	159	3146	478	271	2.7	6.0	37	6.5
	15-30	7	167	3065	640	210	1.1	6.1	25	4.3

Table 2: Monthly and seasonal precipitation and average temperature at the experimental sites, 2012

	Precipitation (mm)				Average temperature (°C)			
Months	Boone 2012	Boone LT	Chariton 2012	Chariton LT	Boone 2012	Boone LT	Chariton 2012	Chariton LT
April	83	92	109	92	12	9	13	11
May	49	117	81	116	19	16	19	16
June	55	133	73	126	22	21	23	21
July	36	110	13	113	26	23	27	24
August	42	110	75	105	22	22	23	23
September	39	81	12	103	18	17	19	18
April to September	304	643	363	655	-	-	-	-

LT = Long Term from 1951-2012

long-term average and that was only by 10 mm. Mean air temperature for April through July was higher than long-term average at Boone and Chariton in 2012 (Table 2). However, August temperatures were normal at both locations.

Soybean pests: Chariton had significantly more prickly sida (*Sida spinosa*), tall waterhemp (*Amaranthus tuberculatus*) and total weeds than Boone (Table 3). Weed community at Chariton was composed of only three species, tall waterhemp yellow foxtail (*Setaria pumila*) and prickly sida (Table 3). Density of tall waterhemp, 50% of the weed community at Chariton was greater in the absence of fungicide seed treatment ($p = 0.07$) (Table 3). The interaction of fungicide seed treatment x biofield energy was significant ($p = 0.07$) (Table 3). Waterhemp density was greater in the absence of fungicide and biofield energy seed treatments compared to other treatment combinations (Table 4). The fungicide seed treatment x location interaction was significant for tall waterhemp ($p = 0.06$) and total weeds ($p = 0.07$) (Table 3). Soybean without fungicide seed treatment at Chariton had greater density of tall waterhemp and total weeds than did soybean with fungicide treatment at Chariton or soybean at Boone regardless of fungicide seed treatment (Table 5). Yellow foxtail (Rose *et al*., 1983) and tall waterhemp (Bauer *et al*., 1991) can greatly decrease yield if competition occurs at critical periods of soybean development (Van Acker *et al*., 1993). Yield losses usually are greatest when interference occurs during reproductive development of soybean but weed density was negligible over those growth stages in this study (personal observation, A. Lenssen).

Table 3: Analysis of variance for three weed species and total weed density

Treatments	Prickly sida (plants m^{-2})	Tall waterhemp (plants m^{-2})	Yellow foxtail (plants m^{-2})	Total weeds (plants m^{-2})
Seed fungicide				
No	7^a	34^a	12^a	53^a
Yes	9^a	3^b	1^a	13^b
Biofield treatment				
No	8^a	31^a	3^a	41^a
Yes	8^a	6^a	10^a	24^a
Location				
Boone	0^b	1^b	2^a	3^b
Chariton	16^a	37^a	11^a	63^a
Significance (p-value)				
Seed fungicide (S)	0.70	0.07	0.11	0.07
Biofield (B)	0.91	0.12	0.34	0.37
S×B	0.51	0.07	0.38	0.18
Location	0.007	0.04	0.22	0.01
S×L	0.70	0.06	0.25	0.07
B×L	0.91	0.10	0.53	0.28
S×B×L	0.51	0.11	0.58	0.17

Means within columns and treatment followed by the same letters or no letter are not significantly different at the 10% level of significance

Foliar diseases often are apparent on soybean in Iowa, however due to prolonged elevated temperatures and low relative humidity in 2012, foliar disease symptoms were not evident. Additionally, the commonly occurring arthropod pest, soybean aphid (*Aphis glycines* Matsumura) was not found at either location during the 2012 growing season due to elevated temperatures (McCornack *et al*., 2004).

Soybean crop: Soybean stand density at VC stage was influenced by location with Chariton site having better seedling recruitment after planting due to better soil moisture (Table 6). Other factors, seed fungicide, biofield treatment and their interactions were not significant ($p>0.10$). At V2 stage, soybean stand density did not differ for seed fungicide, biofield treatment, location or their interactions (Table 6). At soybean maturity, R8 stage, the effects of location and seed fungicide x biofield treatment were significant for stand density (Table 6). Soybean at Chariton had double the stand density at harvest compared to soybean at Boone. Soybean receiving either biofield or seed fungicide treatment had higher stand density at harvest than soybean that did not receive either treatment prior to planting (Table 4). Soybean receiving both biofield and seed fungicide treatments had intermediate stand density to other treatment combinations. Soybean stands in this study were lower than optimal for maximum seed production, however stands were adequate to produce 95% of maximum yield (Weber *et al*., 1966; De Bruin and Pedersen, 2008). Soybean plants have excellent potential for increased branching to compensate for reduced stand denisty (Cox and Cherney, 2011). Consequently, small differences in stand density almost never impact soybean yield.

Aboveground biomass of soybean varied only by location (Table 6). Soybean at Boone produced greater biomass than soybean at Chariton (Table 6). Other factors did not influence soybean biomass. Plants at Boone were taller at harvest than were plants at Chariton, otherwise treatment factors and their interactions did not influence plant height (Table 6).

Table 4: Seed fungicide x biofield treatment interaction means for tall waterhemp density, soybean stand density and soybean seed oil and protein

Seed fungicide	Biofield treatment	Tall waterhemp (plants m^{-2})	Stand at R8 (plants m^{-2})	Seed oil (g kg^{-1})	Seed protein (g kg^{-1})	Seed (No. pod^{-1})
No	No	62^a	19^b	182^{ab}	349^{ab}	1.5^b
No	Yes	6^b	24^a	177^b	353^a	2.2^a
Yes	No	1^b	23^a	181^{ab}	349^{ab}	2.1^{ab}
Yes	Yes	6^b	21^{ab}	184^a	342^b	1.8^{ab}

Means within columns follow by the same letters are not significantly different at the 10% level of significance

Across treatments, pod density averaged 893 m^2. Soybean at Chariton had greater pod density than soybean at Boone but other treatments and all interactions were not significant ($p>0.05$) (Table 6). Conversely, seed per pod was greater at Boone than Chariton, however as for pod density, other treatments and interactions were not significant ($p>0.05$) (Table 6). Seed mass did not vary significantly for any treatment or interaction ($p>0.05$) (Table 6). Soybean yield loss from delayed planting and drought stress is caused by reduction in flower number, pod number and seed fill (Westgate and Peterson, 1993). Precipitation amounts and timing at Chariton allowed greater flower and pod retention than occurred at Boone but abortion during early seed development was greater, likely due to lack of available soil water.

Soybean yield averaged 2478 kg ha^{-1} and was not influence by treatments or their interactions (Table 6). Delayed planting date can result in significant yield loss, however the planting date utilized in this study typically would only have resulted in about a 10% reduction in yield in Iowa (Whigham *et al*., 2000). The dry 2012 growing season resulted in drought and high temperature stress to soybean, decreasing yields (Cox and Jolliff, 1986). The harvest index was greater at Chariton (0.40) than Boone (0.34); other factors did not influence harvest index.

Table 5: Seed fungicide x location interaction means for density of tall waterhemp and total weeds

Seed fungicide	Location	Tall waterhemp (plants m^{-2})	Total weeds (plants m^{-2})
No	Boone	0^c	4^b
No	Chariton	68^a	103^a
Yes	Boone	2^b	2^b
Yes	Chariton	5^b	24^b

Means within columns followed by the same letter are not significantly different at the 10% level of significance

The effects of location and seed fungicide x biofield treatment were significant for seed oil concentration (Table 6). Soybean produced at Chariton had higher oil concentration than seed from Boone. Seed treated with both fungicide and biofield had higher oil concentration than seed treated only with biofield; the other treatment combinations were intermediate (Table 4). Seed protein concentration differed for location and seed fungicide x biofield treatment (Table 6). Seed produced at Boone had greater protein concentration than seed from Chariton. Overall, seed protein concentrations were lower than typically produced by Iowa. Seed treated with biofield alone had greater protein concentration than seed treated with seed fungicide and biofield (Table 4) and may have had enhanced root growth or N fixation. Drought stress is known to decrease N fixation (Serraj, 2003; Sinclair *et al*., 2010), ultimately resulting in lower seed yields and seed protein concentration. The oil and protein yields did not differ for treatments or their interactions (Table 6).

Soil water: Results for analysis of the full statistical model for Soil Volumetric Water Concentration (SVWC) showed significant differences for numerous interactions with location. Given this study was conducted at locations 155 km apart on soils with differing physical properties and rainfall, soil volumetric water concentration data were reanalyzed within location. For both locations, SVWC differed ($p<0.0001$) for the main effects of date and depth (Table 7). The main effects of seed fungicide and biofield treatment and their interaction did not differ significantly ($p>0.10$) influence SVWC at either site. At Boone, the seed fungicide x depth interaction was significant ($p<0.04$) for SVWC (Table 7). The SVWC was greater on 24 July where seed had been treated with fungicide prior to planting than the untreated

Table 6: Analysis of variance for soybean stand, height, yield components, biomass, yield and seed oil and protein

Treatments	Stand VC (plants m^{-1})	Stand V2 (plants m^{-1})	Stand R8 (plants m^{-1})	Height (cm)	Pods (No. m^{-2})	Seed (No. pod^{-1})	Seed (mg)	Biomass (kg ha^{-1})	Yield (kg ha^{-1})	Oil (g kg^{-1})	Oil (kg ha^{-1})	Protein (g kg^{-1})	Protein (kg ha^{-1})
Seed fungicide													
No	25^a	28^a	22^a	78^a	875^a	1.9^a	120^a	6602^a	2444^a	179^a	437^a	351^a	858^a
Yes	26^a	28^a	22^a	76^a	912^a	2.0^a	127^a	6834^a	2511^a	182^a	457^a	346^a	869^a
Biofield treatment													
No	26^a	29^a	21^a	76^a	843^a	1.8^a	124^a	6475^a	2403^a	181^a	435^a	349^a	839^a
Yes	25^a	28^a	22^a	78^a	943^a	2.0^a	126^a	6962^a	2552^a	180^a	460^a	348^a	888^a
Location													
Boone	21^b	27^a	14^b	81^a	703^b	2.3^a	127^a	7399^a	2534^a	172^b	435^a	362^a	916^a
Chariton	30^a	30^a	29^a	73^b	1084^a	1.6^b	123^a	6037^b	2421^a	190^a	459^a	335^b	812^a
Significance (p-value)													
Seed fungicide (S)	0.86	0.95	0.69	0.61	0.79	0.72	0.40	0.70	0.66	0.12	0.46	0.08	0.85
Biofield (B)	0.87	0.63	0.41	0.70	0.47	0.34	0.65	0.42	0.34	0.62	0.35	0.58	0.40
S×B	0.40	0.19	0.01	0.59	0.20	0.09	0.54	0.35	0.66	0.07	0.96	0.07	0.49
Location	0.0003	0.12	0.0001	0.02	0.0043	0.02	0.34	0.05	0.47	0.0001	0.37	0.0001	0.10
S×L	0.72	0.34	0.49	0.35	0.89	0.73	0.45	0.55	0.95	0.79	0.90	0.83	0.97
B×L	0.15	0.75	0.22	0.55	0.50	0.49	0.83	0.74	0.29	0.79	0.25	0.45	0.37
S×B×L	0.11	0.16	0.21	0.59	0.93	0.26	0.97	0.42	0.24	0.91	0.24	0.22	0.32

Means within columns followed by the same letter are not significantly different at the 5% level of significance

Table 7: Analysis of variance for soil volumetric water concentration by location

	Soil volumetric water (%)	
Treatments	Boone	Chariton
Seed fungicide		
No	0.1260^{a}	0.1580^{a}
Yes	0.1210^{a}	0.1540^{a}
Biofield treatment		
No	0.1210^{a}	0.1550^{a}
Yes	0.1260^{a}	0.1580^{a}
Date		
1	0.1170^{b}	0.2200^{a}
2	0.0850^{c}	0.1310^{b}
3	0.1690^{a}	0.1180^{b}
Depth		
8 cm	0.1350^{a}	0.1840^{a}
20 cm	0.1130^{b}	0.1290^{b}
Significance (p-value)		
Seed fungicide (S)	0.3300	0.6200
Biofield (B)	0.3500	0.8300
S×B	0.4200	0.4400
Date (Da)	0.0001	0.0001
S×Da	0.8100	0.5200
B×Da	0.7300	0.8000
S×B×Da	0.1800	0.0050
Depth (De)	0.0001	0.0001
S×De	0.0400	0.5200
B×De	0.7400	0.7400
S×B×De	0.2100	0.6500
De×Da	0.0100	0.0001
S×De×Da	0.3400	0.6170
B×De×Da	0.6300	0.3900
S×B×De×Da	0.9000	0.1700

Means within columns and treatment followed by the same letter are not significantly different at the 5% level of significance

control (Table 8). However, SVWC did not differ between fungicide seed treatment on the other sampling dates. Although, some foliar-applied fungicides may change photosynthetic gas exchange in soybean and other crops, results are lacking that document an improvement in water use efficiency of plants grown under drought stress (Nason *et al*., 2007).

The interaction of depth x date was significant ($p<0.0001$) for SVWC at Boone and Chariton (Table 7). On 3 August at Boone, SVWC was greater at 8 cm depth than the 20 cm depth (Table 8); differences between depths were not significantly different on other dates. At Chariton, SVWC was greater at 8 cm depth than 20 cm depth on 12 July and 3 August. The SVWC was similar between depths on 24 July. The interaction of seed fungicide x biofield treatment x date was significant ($p<0.005$) for SVWC at Chariton. On 12 July, the utilization of seed fungicide and biofield treatments resulted in greater SVWC than for soybean with seed fungicide in the absence of biofield treatment and biofield treatment in the absence of seed fungicide (Table 9). On 24 July, the utilization of biofield treatment with the absence of seed fungicide resulted in greater SVWC than in the absence or presence of both seed fungicide and biofield treatments (Table 9). The SVWC was similar among all treatments on

Table 8: Seed fungicide x date and depth x date interaction means for soil volumetric water concentration

	Mean volumetric water (%)		
Parameters	12 July	24 July	3 August
Seed fungicide			
Boone			
No	0.120^{a}	0.086^{b}	0.172^{a}
Yes	0.114^{a}	0.114^{a}	0.165^{a}
Depth (cm)			
8	0.121^{a}	0.090^{a}	0.193^{a}
20	0.113^{a}	0.081^{a}	0.144^{b}
Chariton			
8	0.289^{a}	0.126^{a}	0.138^{a}
20	0.154^{b}	0.136^{a}	0.096^{b}

Means within parameter and date followed by the same letter are not significantly different at the 5% level of significance

Table 9: Seed fungicide x biofield treatment x date interaction means for soil volumetric water, Chariton

		Mean volumetric water (%)		
Seed fungicide	Biofield treatment	12 July	24 July	3 August
No	No	0.231^{ab}	0.109^{b}	0.125^{a}
No	Yes	0.203^{b}	0.158^{a}	0.123^{a}
Yes	No	0.204^{b}	0.146^{ab}	0.115^{a}
Yes	Yes	0.243^{a}	0.112^{b}	0.107^{a}

Means within date followed by the same letter are not significantly different at the 5% level of significance

3 August. The SVWC can vary among treatments for a number of reasons, including both increased and decreased water capture or water use. In this study, SVWC was low at both sampling dates in July and likely negatively impacted shoot and root growth (Hoogenboom *et al*., 1987), decreasing seed yield and protein concentration (King and Purcell, 2001). The lower SVWC at Chariton on 3 August when soybeans were in reproductive development, likely decreased the final number of seed per pod, reducing yield.

CONCLUSION

Density of tall waterhemp was lower in soybean receiving biofield treatment compared to soybean that did not receive seed fungicide and biofield treatments. Additionally, biofield treatment resulted in greater soybean stand density at R8 developmental stage and greater seed per pod compared to soybean not receiving seed fungicide and biofield treatments. However, pod density, seed mass, aboveground biomass and seed yield were not influenced by fungicide seed or biofield treatment, perhaps due to the high level of yield compensation in soybean. Soil volumetric water content varied by seed fungicide x biofield x date interaction but differences were not consistent among treatment combinations. Overall, seed fungicide and biofield treatments had similar effects on soybean productivity. Additional research is required to determine if biofield treatment can replace seed fungicide application in soybean production systems.

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